Earth Science Enterprise Technology Planning Workshop

Large, Lightweight Deployable Antennas

Co-Chairs:
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Facilitator:
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23-24 January 2001

Breakout Session Attendees

Anders, Roland - Northrop
Bekey, Ivan - Bekey Designs
Bobcyk, Wayne - Ball
Brown, Mike - NRL
Bukulic, Bob - APL
Chase, Peter - TRW/Astro
Cosmo, Mario - SAO
Cravey, Robin - NASA/LaRC
Dobson, Craig - U Mich
Doiran, Terence - NASA/GSFC
Edelstein, Wendy - JPL
Entekhabi, Dara - MIT
Farley, Rodger - NASA/GSFC
Fujita, Tosh - JPL
Garza, Mario - Orbital
Gierow, Paul - SRS Tech
Grahne, Mark - ILC Dover
Higashi, Bob - Honeywell
Im, Eastwood - JPL
Jackson, Tom - USDA
Kajii, Makoto - NASDA
Kakar, Ramesh - NASA HQ
Lou, Michael - JPL
Marks, Geoff - TRW/Astro
Neeck, Steve - NASA/GSFC
Njoku, Eni - JPL
Ramat-Samii, Yahya - UCLA
Reed, Bill - TRW
Roler, Max - Sverdrup
Rosen, Paul - JPL
Ruebsamen, Dale - Honeywell
Ruf, Chris - U Mich
Schaubert, Dan - U Mass
Schulze, Ron - JHU/APL
Showen, Robert - Raytheon/Ames
Swift, Cal - U Mass
Talley, Michael - NASA/LaRC
Tupper, Michael - CTD
Walter, Steven - Aerojet
Willey, Cliff - JHU/APL
Williams, Liz - NASA HQ
Woods-Vedeler, Jessica - NASA/LaRC
Yueh, Simon - JPL

Requirements for Large, Lightweight Deployable Antennas: Planar Arrays

Science / Measurement

- Soil Moisture Radiometer
  - 10 km horizontal resolution
  - 1 to 3 day revisit time
- GEO Atmospheric Sounder
  - 60 GHz Temperature Channel
  - 183 GHz Water Vapor Channel
  - 50 km horizontal resolution
- Topography/Hazards SAR
  - 10-30 m horizontal resolution
  - 8 day revisit time
- Biomass/Freeze/Thaw SAR
  - 0.1 to 1 km horizontal resolution
- Precipitation Radiometer
  - 3 hour revisit time
  - Constellation
- Subsurface Probing
  - 50-200 MMz

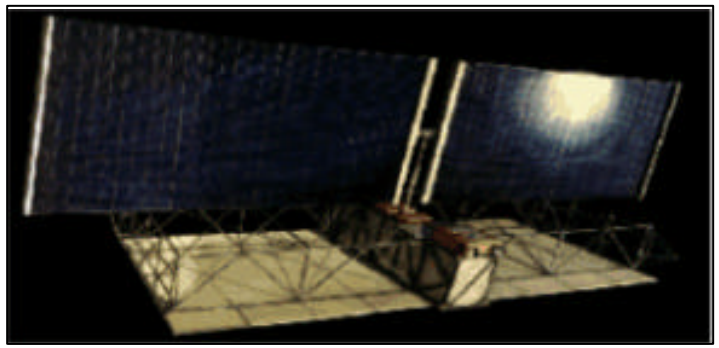
Missions Enabled/Enhanced

- EX4 A - Soil Moisture Mission
- GEO Sounder Mission
- EOS Hazards Mission
- EX ?: Freeze/Thaw Mission

Description of Technology

- Soil Moisture Radiometer
  - 20 x 20 m flat panel array antenna
- GEO Atmospheric Sounder
  - 5 x 5 m flat panel array antenna
- Topography/Hazards SAR
  - 3 x 10 m flat panel array antenna
- Biomass/Freeze/Thaw SAR
  - 3 x 10 m flat panel array antenna
- Precipitation Radiometer
  - 3 x 3 m flat panel array antenna

Illustration of Technology



State of the Art for Large, Lightweight Deployable Antennas: Planar Arrays

State of the Art for the Technology

- 10 x 3 m mechanically-deployed SAR Antenna (TRL9 - STRM)
- Inflatable Deployable SAR Antenna
  - Lab Demo (TRL4)
    - 3x1 m Inflatable Array
    - 0.5 to 1 mm flatness
  - Engineering Model (TRL 3)
    - 3 x 5 m Single-Wing Inflatable Array

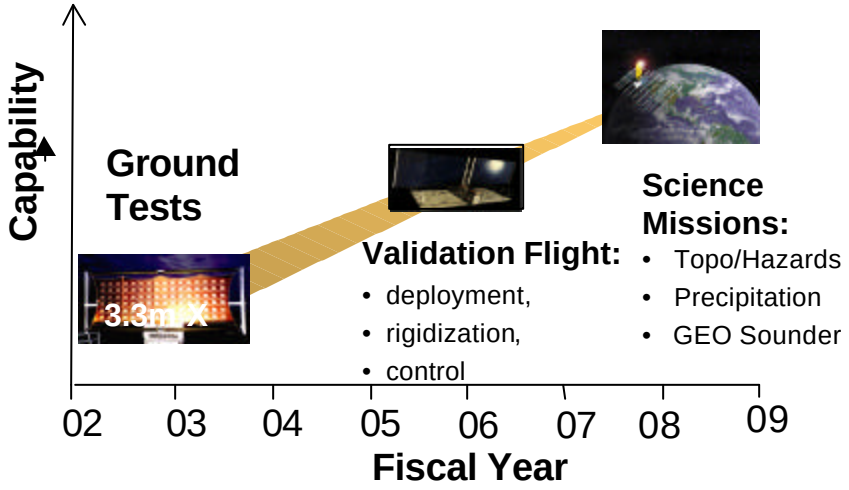
Illustration of State of the Art

3.3m x 1m L-band
Inflatable SAR radar array

Major Technology Elements and TRL

- Lightweight Space Deployable Structure
  - NGST sun shade (TRL 3 - 4)
  - active control of structure (TRL 4)
- Membrane
  - surface profile (TRL 4 for 1 x 3 m)
  - surface roughness (TRL 3)
  - material survivability (TRL 4)
  - handling, packaging, thermal control (TRL 3)
  - alternate materials (TRL 3-4)
- Focal Plane Compensating Arrays (TRL 3)
  - beam efficiency
  - polarization

Technology Roadmap



Requirements for Large, Lightweight Deployable Antennas: Reflector Antennas

Science / Measurement

- LEO Rain Radar
- Soil Moisture Radiometer
- GEO Rain Radar
- Ocean Salinity
- Ocean Surface Wind Vector

Missions Enabled/Enhanced

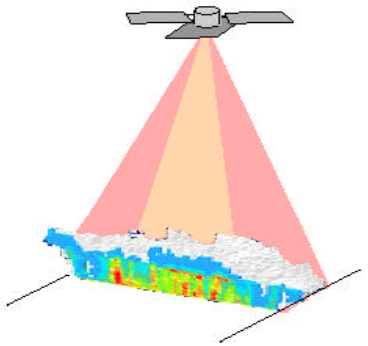
- Soil Moisture Mission
- EOS Hazards Mission
- GPM Follow-on
- EX4B Ocean Salinity

Description of Technology

Inflatable, rigidizable or mechanical structure with surface mesh or membrane

- Spin Scanned Reflector
- Spin-Scanned Feed
- Push-Broom

Illustration of Technology



Rain Radar based on a 5 x 5 m cylindrical push-broom antenna

State of the Art for Large, Lightweight Deployable Antennas: Reflector Antennas

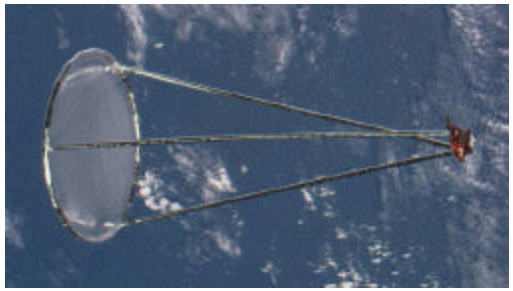
State of the Art for the Technology

- Inflatable Deployable Dish Antenna
  - STS-77 Spartan Inflatable Dish Antenna Demo (TRL 5)
    - Inadequate surface smoothness
    - No demonstration of rigidization
  - Attainment of design shape in space
- TRW Large Mesh Antenna
  - Space qualified 12.5m @ L-band
  - Extendable in size and frequency
  - Microwave emissivity requires evaluation

Major Technology Elements and TRL

- Lightweight Space Deployable Structures
  - Mechanically deployable structures (TRL > 4)
  - Inflatable structures (TRL 2-4)
  - Active control of structure (TRL 2)
- Membrane
  - Surface profile (TRL 4 for 1 x 3 m)
  - Surface roughness (TRL 3)
  - Material survivability (TRL 4)
  - Handling, packaging, thermal control (TRL 3)
  - Microwave emissivity requires evaluation
- Subreflector and focal plane compensation methods
- Shape and RF metrology

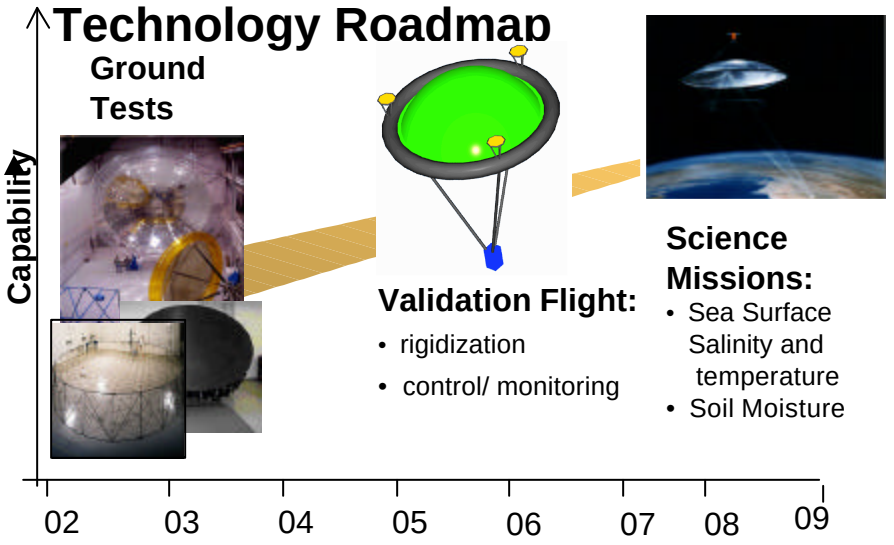
Illustration of State of the Art



Inflatable Antenna Experiment

- Uncontrolled deployment
- Space validation of surface accuracy not achieved

Technology Roadmap



Science and Technology Drivers for Large, Lightweight Deployable Antennas

Science Element	Driving Requirements						
	Freq.	**Size**	**Pol**	**Swatch**	q_i	**Other**	
Precipitation	≥ 10	≥ 3m	Dual Lin.	± 50°	Const.	• Multiple frequencies • Pointing accuracy • Active and passive	↑ Better Spatial Resolution And More Frequent Revisits ↓
Soil Moisture	1.4	25m	Dual Lin.	± 50°	---	• Beam Efficiency >95% • Low loss < 0.3dB • Pointing Accuracy	
Ocean Salinity	1.4	6/25m	Dual Lin.	± 50°	Const.	• Beam Efficiency > 97% (Earth <1%; Sky < 3%) • Low loss < 0.3dB • Pointing Accuracy	
Interferometric SAR	1.2	50m GEO	Dual Lin.	Full Disk		• High Power • Pointing Accuracy	
Ocean Surface Wind Vector	13	6m	Dual Lin.	± 65°	---	• Cross-pol < -35dB • Pointing Accuracy	
Microwave Sounder	> 50	6m	Lin.	Full Disk		• Pointing Accuracy	
SubSurface SAR	0.05-0.20	>25m	Dual Lin.	---	---	• High Power	
Recipitation Radar (LEO)	14/35	6m	Dual Lin.	± 37°	---	• Match-beam at 2 frequencies • Sidelobe < 30 dB • Cross-pol < 25 dB	
Hurricane Monitoring Radar (LEO)	35	25m	Dual Lin.	8° Full Disk			
Communications	≥ 10	3m	CP	---	---	• Pointing Accuracy	

Validation of Large, Lightweight Deployable Antennas: Planar Arrays

Description/Justification of Proposed Space Validation

- Deployment, rigidization, control and monitoring of large deployable structure
  - Validate rigidization, gas release
  - Structural accuracy and stability
  - Characterize vibration/ thermal shock
  - Validate material characterization and survivability
- RF performance
  - Validate loss, cross-pol isolation, calibration for radars
  - Validate loss, cross-pol isolation, beam efficiency and calibration for radiometers

Accommodation Requirements

- 3 x 10 m test antenna
  - Mass 150 kg (50 kg for antenna alone)
  - Volume 3.5 by 0.5 by 1 m
  - Power
    - Deployment (TBD)
    - Operations (SAR - 500 Watts; Radiometer - 50 Watts)
  - Data Rate (TBD)
- Shuttle, free flyer, or space station (TBD)

Expected Benefits

- Flight needed to validate structure/thermal design tools
- Validate deployment, rigidization, and on orbit control needed to mitigate risks
- Validate RF performance
- Validate radiometer calibration

Top-Level Development and Flight Schedule

- L-band ready for flight
  - Phase A FY01
  - Phase B FY 02
  - Validation Flight FY 2004-2005
- Science mission implementation
  - As early as FY 2007

Validation of Large, Lightweight Deployable Antennas: Reflector Antennas

Description/Justification of Proposed Space Validation

- Deployment, rigidization, control and monitoring of large deployable structure
  - Demonstrate rigidization, gas release
  - Structural accuracy and stability
  - Characterize vibration/ thermal shock
  - Demonstrate material characterization and survivability
- Pointing
  - Rotating antenna
  - Rotating feed horn
- Figure Variation vs Radius
- Radiometric performance
- Effects of outgassing and thermal loads on pointing stability
- Active Control of optics and structures

Accommodation Requirements

- Mass 150 kg
- Small stowed volume
- Surface and antenna-pattern metrology (TBD)
- Power (TBD)
  - Deployment
  - Radar
  - Radiometer

Expected Benefits

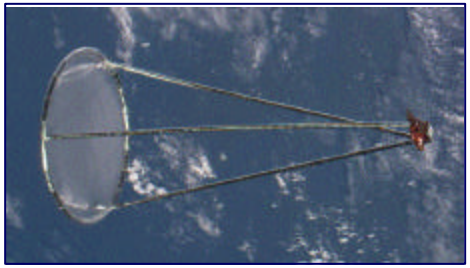
- Flight needed to validate structural/thermal performance
- Validate lightweight deployment (and rigidization)
- Validate radiometer quality (Beam efficiency, cross-polarization isolation and surface reflectivity/emissivity)
- Demonstrate on-orbit control of large, rotating space structure

Top-Level Development and Flight Schedule

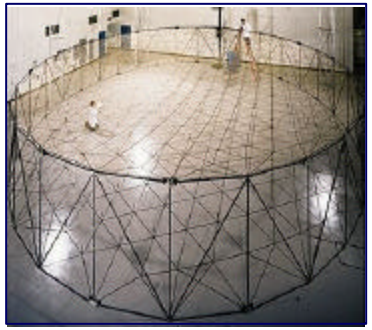
- 10 m class antennas ready for flight validation
  - Phase A: FY 02
  - Phase B FY 03
  - Validation Flight FY 2005-2006
- Science mission implementation
  - As early as FY 2008

Large Deployable Antennas Benefit Multiple Earth Science Applications

Inflatable Deployable Antenna

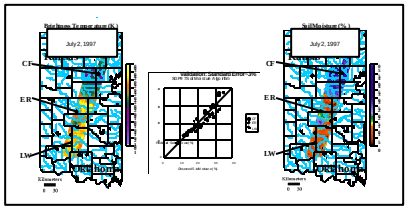


Large Deployable Mesh Antenna



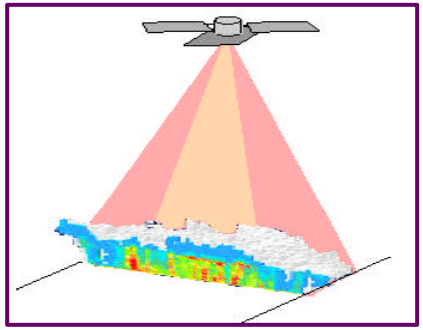
Planar Array Antenna

Soil Moisture Measurements



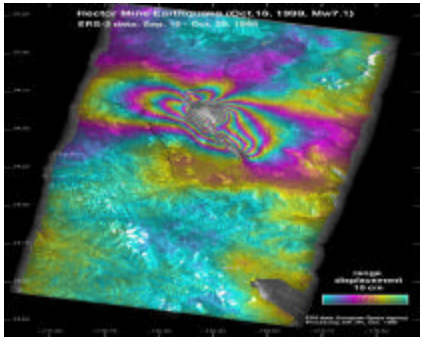
- 25m class antennas for 10km horizontal resolution

Global Precipitation/Salinity/Ocean Wind Vector Measurements



- 5-20m class antenna for 2km horizontal resolution with wide-swath scan
- Potential extension to geostationary orbits
- Potential extension to LEO constellations

Natural Hazard



- 3x10m antennas for wide-swath/high SNR
- Potential extension to geostationary orbits
- Potential extension to LEO constellations

Roadmap for Large, Lightweight Deployable Planar Arrays

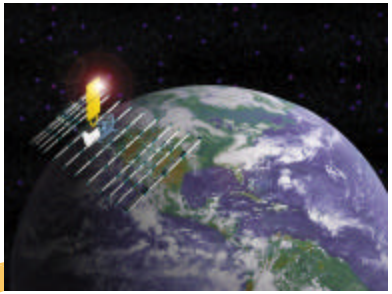
Requirements:

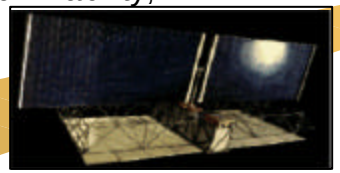
•Science Drivers

- Soil Moisture Radiometer
- SARs for Topo/Hazards,
- Biomass Freeze/Thaw
- GEO Atmospheric Sounder
- Ocean Surface Winds
- Global Precipitation
- Sea Surface Salinity and Temperature

Technology Drivers

- Lightweight space deployable structure
- Membrane flatness, surface roughness, survivability,
- Packaging/deployment/control
- RF bandwidth, losses, calibration





Science Missions:
(with large deployable planar array antenna)

- Topo/Hazards
- Precipitation
- GEO Sounder

Validation Flight:
Validate deployment, rigidization, control and monitoring of 3x10m inflatable antenna

- Mass 50kg for antenna
- Validate deployment, rigidization, space survivability
- Structural accuracy/stability for 1 to >10 GHz
- Characterize vibration/thermal behavior
- Demonstrate material survivability
- Verify performance for radiometer

Ground Tests

Capability

01 02 03 04 05 06 07 08

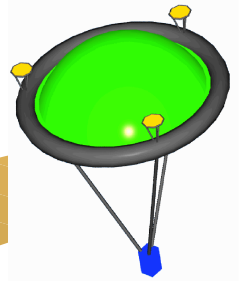
Fiscal Year

Roadmap for Large, Lightweight Deployable Reflector Arrays

Requirements:

- **Science Drivers**
  - Soil Moisture and Ocean Salinity Radiometers
  - Rain Radars
  - Ocean Surface Wind Vector
- **Technology Drivers**
  - Lightweight space deployable structures
  - Membrane shape, surface roughness, survivability, packaging/deployment/control
  - Microwave emissivity
  - Shape and RF metrology
  - Subreflector and focal plane compensation

Science Missions:
(with 20-25 m class deployable reflector)
- Sea Surface Salinity and temperature
- Soil Moisture



Validation Flight:

Demonstrate rigidization, control and monitoring of large inflatable antenna
- 25m diameter class antenna, 150 kg
- Shape control of antenna surface
- Measuring shape and smoothness for 1 to 100GHz
- Control of flexible structure dynamics
- Pointing accuracy/control
- Effects of out-gasing/thermal loads

Adaptive Subreflector

Ground Tests

Capability

01 02 03 04 05 06 07 08

Fiscal Year